Effect of the non-fertilizer N supply of grassland soils on the response of herbage to N fertilization under mowing conditions

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Received 16 December 1994. Accepted in revised form 10 March 1995

Key words: apparent N recovery, grassland, non-fertilizer N supply, N use efficiency, optimum fertilizer application rate

Abstract

I tested whether the non-fertilizer N supply of grassland soils (NFNS; N uptake on unfertilized plots) affects the relationships between N uptake and dry matter production, N application and N uptake, N application and dry matter production, as well as the optimum fertilizer application rate.

At low N uptake rates the amount of dry matter production per kg of N uptake was negatively correlated with NFNS; at higher N uptake levels the correlation was not significant. The apparent nitrogen recovery of fertilizer N was not correlated with NFNS. The optimum fertilizer application rate was correlated positively with the maximum dry matter production (Max DM) and negatively with NFNS. The relationship optimum fertilizer application rate = \(-81 - 0.8 \times \text{NFNS} + 0.0375 \times \text{Max DM}\) accounted for 89% of the variance in optimum fertilizer application rate between soils at a marginal N effect of 7.5 kg dry matter per kg N applied. So an increase in NFNS of 100 kg N resulted in a decrease of the optimum N application rate of 80 kg N.

Introduction

Until recently, the N fertilizer recommendation for intensively managed mown grasslands on mineral soils in the Netherlands was 400 kg N ha\(^{-1}\) yr\(^{-1}\) irrespective of soil characteristics. This recommendation was based on the results of field experiments in the early seventies; the optimum application was defined as the level of N input at which the response falls to less than 7.5 kg dry matter per kg N applied (marginal N response; \(N_7\)\(\text{,}_5\)); in the UK the optimum was defined at \((N_{10})\) (Morrison et al., 1980; Prins et al., 1980; Prins, 1983). It is now realized that this recommendation was too general and that soil characteristics should be taken into account to improve the recommendation for N fertilizer application (Ruitenberg et al., 1991). The N uptake on unfertilized fields gives a good estimation of the non-fertilizer N supply (NFNS; Warren and Whitehead, 1988). NFNS consists of soil organic N that is mineralized during the growing season, inorganic N present in the soil profile in spring, dry and wet deposition and biological N fixation (Ruitenberg et al., 1991). In the absence of clover, differences in NFNS between locations are mainly due to differences in mineralization of soil organic N. As grass derives its N not only from applied fertilizer, but also from sources that are included in NFNS, the level of NFNS should affect the response of herbage to N fertilization and the optimum N fertilizer application rate. Optimum fertilizer application rates in the Netherlands and in the UK range from 260 to 540 kg N ha\(^{-1}\) yr\(^{-1}\) for mineral soils (Ruitenberg et al., 1991) and are affected by NFNS and water supply (Ruitenberg et al., 1991; Salette, 1988; Whitehead et al., 1981).

The relationship between N application rate and dry matter production is the result of NFNS, the relationship between N application and N uptake and the relationship between N uptake and dry matter production (Frankena and De Wit, 1958; Fig. 1). Environmental conditions affect the apparent recovery of N fertilizer (ANR; i.e. N uptake by the fertilized sward
minus that by the control expressed as a percentage of the N applied) and the efficiency of the N taken up (NUE; nitrogen use efficiency, i.e. the response in dry matter production per kg of N taken up by the sward); ANR and NUE are higher at optimum conditions for plant growth than at suboptimal growing conditions (Garwood et al., 1980; Ruitenberg et al., 1991). The level of NFNS could also affect the ANR and NUE. Salette (1988) observed that at low N uptake levels, NUE was higher on a soil with a low organic matter content than on a soil with a high organic matter content. When NFNS affects NUE or ANR, an increase in NFNS does not necessarily lead to a corresponding decrease in the optimum fertilizer application rate.

The aim of this paper is to test whether NUE and ANR are affected by NFNS and to what extent differences in NFNS affect the optimum fertilizer N application rate.

**Materials and methods**

**Field experiments**

I analyzed N fertilization of mown grasslands in experiments that were performed by the Nutrient Management Institute (NMI-Wageningen) and the Research Station for Cattle, Sheep and Horse Husbandry (PR-Lelystad) at different locations in the Netherlands. Information about the characteristics of these soils and their NFNS is given in Table 1. The rates of fertilizer N that were applied ranged from 0 to 550 kg N per ha per year. In spring, fertilizer N (calcium ammonium nitrate) was applied in all treatments when the accumulated mean daily air temperature above 0 °C since 1 January was approximately 200 (Jagtenberg, 1970). Thereafter, applications were made in diminishing amounts until target rates were reached. Grass was mown when the treatments with the highest N application rate reached a dry matter yield of approximately 2500 kg dry matter per ha. Fertilizer was again applied immediately thereafter.

In March 1991, tensiometers were installed at 20 cm depth at four different sites to determine the water potential three times a week.

**Statistical analysis**

For each soil and in each year, the relationships between N uptake (N in the mown grass) and dry matter production and N application and dry matter production were fitted with a Mitscherlich curve (Genstat, 1987). From the relationship obtained between N application and dry matter production the maximum dry matter production (Max DM) on a soil was estimated.

To test whether NFNS affected the relationship between N application and dry matter production, the N application rate at which the marginal N effect was 15, 10 and 7.5 kg dry matter per kg of N applied was determined.

The following relationships were analyzed with correlation techniques (Genstat, 1987): i) between NFNS and the apparent recovery of fertilizer N, ii) between NFNS and the dry matter production at N fertilizer application levels of 0, 100, 200, 300 and 400 kg N ha⁻¹, iii) between NFNS and the dry matter production of the herbage for each successive 100 kg N ha⁻¹ taken up by the herbage, and iv) between NFNS and N₇.₅, N₁₀ and N₁₅. The dry matter production at a certain N fertilizer application rate, the dry matter production at a certain amount of N taken up by the herbage and N₇.₅, N₁₀ and N₁₅ were estimated from the obtained Mitscherlich curves for each individual soil.

Not only NFNS, but also Max DM was correlated with the optimum fertilizer N application rate, as it has been observed that N₇.₅ for sandy grassland soils is related to maximum dry matter production (Noy, 1989).